(19) Europäisches Patentamt
European Patent Office
Office europeen des brevets

(11) EP 0 377 673 B1

EUROPEAN PATENT SPECIFICATION

(12)

(45) Date of publication and mention of the grant of the patent: 21.05.1997 Bulletin 1997/21

(21) Application number: 88909561.8

(22) Date of filing: 29.07.1988

(51) Int. Cl.[6]: A63B 53/14

(86) International application number: PCT/GB88/00629

(87) International publication number: WO 89/00875 (09.02.1989 Gazette 1989/04)

(54) GOLF CLUB
GOLFSCHLÄGER
CLUB DE GOLF

(84) Designated Contracting States: AT BE CH DE FR GB IT LI NL SE

(30) Priority: 29.07.1987 GB 8717964

(43) Date of publication of application: 18.07.1990 Bulletin 1990/29

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(56) References cited:
EP-A- 0 227 347
US-A- 4 674 746

Remarks:
The file contains technical information submitted after the application was filed and not included in this specification

EP 0 377 673 B1

Printed by Rank Xerox (UK) Business Services
2.14.0/3.4

Description

The present invention relates to sporting equipment and more particularly to improvements in or relating to the design of golf clubs, hereinafter referred to as clubs.

With known designs of clubs the weight, for any given weight of club, tends to be concentrated at the head of the club and whilst for the professional player this weight is controllable during striking of the ball for the amateur player the ball is often wrongly struck.

US Patent No. 4,674,746 and EP 0,227,347 describe golf clubs in which weight is added in the gripping area. US 4,674,746 also describes a golf club in which the head weight is lightened.

It is an object of the present invention to provide a club with a weight distribution which enables the amateur player to strike the ball with greater accuracy by controlling the inertia in both the first and second phases of movement of the golf club during the swing.

According to the present invention there is provided a golf club characterised as in claim 1,

According to the present invention there is also provided a method of matching a golf club to a player as claimed in claim 8.

Embodiments of the present invention will now be described, with reference to the accompany drawings, in which :-

Figure 1 shows a set of tables illustrating the variation of the ratio of torque applied by the player to the torque actually applied to the club;

Figure 2 shows the ratios of the inertia values of the club for the first and second phases of the swing;

Figure 3 illustrates the range of positions of the added weight on the golf club; and

Figures 4a to 4g illustrate various designs of weight for the golf club of Figure 3.

The designs of golf clubs have changed significantly over recent years and many technological advances have been made. New materials have been used in place of the conventional iron and wood heads, new shapes of head with better aerodynamics and different weight distribution have been tried, and shafts of reinforced plastic are becoming common, particularly in the United States and Japan. However the fundamental make up of the club remains the same. Of the overall weight of 350 to 500 gms, typically 60% is in the head, 30% in the shaft and 10% in the grip.

The dynamics of the swing of any piece of sporting equipment are complex. The equations of motion are however relatively straightforward and lead to general qualitative solutions. To specify the quantitative solutions for particular cases requires a knowledge of the forces that come into play, applied by the human frame, arms and wrists and these are not well defined. To proceed to a solution previous researchers have therefore used observations of professional swings. The constants in the equations can then be determined from these observations and the calculated patterns of the swing compare well with the actual swing.

Two particular pieces of existing research are relevant to this invention.

1. Williams, D. The Dynamics of the Golf Swing. Quarterly Journ. Mech & Applied Math Vol XX Pt 2 1967.

2. Jorgensen T. On the dynamics of the swing of a golf club. American Journal of Physics. Vol 38 No 5 May 1970.

Although their treatment of the equations is different they both show that there is an 'optimum' way to swing the club to achieve the maximum clubhead velocity at the impact of club and ball, for a given energy input. This maximisation of velocity is very important in that not only does it cause the ball to travel longer distances with the driver and long irons but it causes the generation of much backspin on the ball for short irons, which is essential for good shots to the green. Any deviation from the optimum swing not only reduces the velocity at impact but also significantly changes the line of the swing. The clubhead/ball impact is not square and the ball often slices away on a curve to the right (for a right-handed player). Golfers often refer to this phenomenon as hitting from the top. The significance of this phrase is the essence of this invention.

First consider the implications of the work of Williams and Jorgensen. The optimum swing can be described, beginning from the completion of the backswing, as follows:

The body and arms of the golfer accelerate the club from rest at about $20 m/s^2$. The wrists remain cocked in the position attained at the top of the swing. This phase continues with the wrists still locked in position for approximately 60 to 65 degrees of rotation of the body with the acceleration rising to $300 m/s^2$. At this stage, and no earlier, the wrists begin to uncock. The hands continue in an arc at roughly constant velocity and the club rotates with increasing angular velocity about them. The velocity of the clubhead therefore has two components, that due to the speed of the hands and that due to the rotation of the club about them. If the swing has been timed correctly the hands will reach the bottom of the swing at the exact moment that the clubhead reaches the bottom. This is the condition that Williams and Jorgensen refer to as optimum.

The attainment of such a swing is governed by the muscular effort of the swinger and the weight of the components he is swinging. Many muscles are used in the effort and to achieve the optimum they must be combined in a particular way. It is particularly important for the first phase of the swing (where the wrists remain cocked) to encompass the full angle mentioned above. Only then will the uncocking process of the wrists bring the clubhead square on impact and at high speed. Now all tests and research has so far been conducted mainly on professional golfers or golfers with excellent swings. These individuals have generally been brought up to play the game from an early age, or have had the benefit of a natural talent for the game or a good teacher and much practise of the correct manner of swinging. Thus the muscles, and specifically the balance between the muscles, is developed to suit the requirements of a good swing. (An obvious example of this, in another sport, is the gross development of the arm of a professional tennis player). True there are individuals who have what appear to be poor swings even in the ranks of the professional but eventually they acquire the ability to bring the clubhead square at impact. The time and effort to do this is beyond the means of the general amateur player. Most amateurs, particularly men, come to the game when their balance of muscles is very inappropriate to a good golf swing. They have strong back and leg muscles, and moderate upper arm muscles. They are able to lock the wrists in the direction of the line of the arms as would be required for lifting heavy weights, but they lack the ability and strength to control the rotation of the wrists about the arms under a large load. In the swing this load comes from the very large centrifugal accelerations generated at the clubhead during the first phase of the swing. Consider now the swing of an amateur golfer:

The body and arms accelerate the club from rest at the top of the backswing. Being strong in the back and leg this acceleration can be as high and sometimes higher than a professional golfer achieves. However the weakness of the wrists does not allow him to complete the first phase of the swing with the wrists firmly cocked. The clubhead, under high centrifugal accelerations, begins to rotate about the arms. Because of this the clubhead moves out of the desired plane of the swing and continues to do so for the rest of the swing. Impact is often made with the clubhead moving from the outside to inside of the correct plane. Clockwise spin (looking down on top of the ball) is created on the ball which results in a curved motion of the ball in flight commonly known as a slice. In addition the maximum clubhead velocity is not achieved at impact. The combination of these failings results in a poor shot.

One solution to the problem is to reduce the speed of the club and the arms in the first phase. If this can be made to match the resistance of the wrists at the correct angle of completion of this phase then the subsequent impact will be square. The maximum velocity of the clubhead will now occur at impact but the magnitude of this velocity will be less than the professional, with stronger wrists, can achieve. In effect the result is that the ball will travel straight and true but will carry less distance than the professional's shot produces. This is infinitely preferable to a short slice, the most common shot in golf. Armed with the correct sequencing of the shot the golfer may now, if he wishes, develop the muscles of the lower arm (and only these muscles) to enable him to produce a quicker version of his basically sound new swing thereby achieving longer distances of shot. This definition of the swing also shows why golfers find it easier to swing the 'short' irons since with these clubs the swing angle is much less and the accelerations much smaller. This ideally sequenced swing is often referred to as the grooved swing.

The imbalance of muscular effort is also seen in the young player, particularly if they are also playing another sport more common to school activities than golf. The principles outlined here are equally applicable to this category of player.

The golf professional, and many other knowledgeable teachers, are often heard to remark on the speed of the swing of the amateur. A slower swing is said to produce better 'timing' of the shot. The explanation given above shows why this is the case.

For most amateurs this change to a slower swing is nearly impossible to achieve and another solution to the problem must be sought.

From a technical appreciation of the swing, a study of an analysis of the mathematics of it and a deep knowledge of the game from the points of view of the amateur and the professional, we have invented a club which aids the amateur to generate the correctly sequenced swing. It is of benefit to all amateurs who, no matter what their standard, will hit bad shots and to professionals in that it is more controllable.

The technical explanation of the design is as follows. Jorgensen shows that the equations of motion of the swing result in:

$$T_s = \ddot{\theta}\,[J + MR^2 + RS\cos(\psi - \theta)] + \ddot{\psi}[I + RS\cos(\psi - \theta)] - [\dot{\psi}^2 - \dot{\theta}^2]\,RS\sin(\psi - \theta)$$

$$T_c = \ddot{\psi}\,I + \ddot{\theta}\,RS\cos(\psi - \theta) + \dot{\theta}^2\,RS\sin(\psi - \theta)$$

T_s = torque applied to the system by the golfer

T_c = torque applied to the club
J = moment of inertia of the arms taken about an axis through the spine
G = first moment about the same
I = moment of inertia of the club about the golfers wrists
S = first moment about the same axis
R = effective length of the golfers arms
ψ = angle between the club and the horizontal
θ = angle of rotation of the system from the horizontal

The torque T_c, applied to the club basically involves the first (S) and second (I) moments of the club about the golfers wrists. If these can be decreased then the torque reduces. In consequence the amateur golfer would find it much easier to control the natural uncocking of the wrists and delay this process until the correct period of the swing. In addition the professional golfer will find the club easier to manipulate for different types of shot. These moments involve the mass of the clubhead, the mass of the shaft and the length of the shaft. It is noted that the last quantity decreases for the short irons but the head weight is increased to keep the swing weight (which is in effect the first moment) constant. Assuming therefore that the shaft weight remains the same, the mass of the head would need to be reduced to reduce T_c. This can be easily done by redesigning the head accordingly. However, the same terms appear in the first equation for the torque T_s, applied by the body and legs. In essence therefore the balance has not been changed between the two components of torque and what will be achieved is merely a faster version of the incorrectly sequenced swing. This in part, explains why lightweight clubs have never been successful. If weight is now added to the club in the vicinity of the golfers hands two effects occur. First the overall weight of the club increases. This increases the torque T_s (by virtue of the term MR^2) and reduces the speed with which the club is swung from the top. The torque T_c, of the second phase remains virtually unaltered since the weight is placed high on the shaft. We have therefore achieved a change to the balance of the club, and therefore the balance of muscular effort required to swing it, which can be made to match the requirements of the amateur golfer. This club design increases the inertia to maintain a slow swing from the top in the first phase which can now be completed without the wrists uncocking, thereby producing the correct sequencing of the swing.

Figure 1 for instance shows the percentage decrease in the ratio T_c/T_s for a 6 iron and a driver, for different added weights and different positions of these weights. It is concluded from this that the positon of the weight is much less important than the magnitude of the weight. Larger changes to the ratio come with larger added mass. A comparison is also shown for a lightened head. A balance has to be struck between achieving a significant change to the ratio between the torques required in each phase and the difficulty of swinging a heavy club. In essence it would be preferable therefore to keep the inertia over the first phase of the swing high whilst having a low inertia in the second phase. This can be done by combining the two changes described in Figure 1, using a light head mass and a separate added mass in or near the gripping area.

Figure 2 plots the calculated results of doing this for a range of values of head mass and added weight. The lower vertical lines show the range of inertia ratios.

$$(I + MR^2)/I$$

for current clubs. Within each range are ladies clubs, heavy headed gents clubs, using composite and steel shafts in a range of lengths. By decreasing head weights from the current range by between 13% and 30% and adding suitable weights in various locations around the gripping area, the inertia ratios are greatly increased. The vertical lines show the range achieved again using ladies clubheads, gents clubheads and composite or steel shafts of various lengths. The criteria used for these calculations is that the inertia for the first phase should be within ± 5% of the value for the standard club and the inertia for the second phase should be reduced by at least 20%. In fact values up to30% are contained in the range.

It should be noted that the range of ratio values is very much larger than in current clubs, enabling the designer to select clubs for the wide range of abilities of golfers.

Another benefit of the design is also shown in Figure 2. Whereas the inertia ratio for a current driver is much less than for a current seven iron, reflecting the greater difficulty in using the driver, it is possible with the proposed invention to design clubs which have roughly constant ratios across the range of loft values.

The weight added to the shaft of the club in the region of the gripping area is preferably greater than 50 gms and may be between 80 and 160 gms. The centre of gravity of the additional weight is within a distance of 300 mm from the butt end of the shaft.

The head of the club is preferably lightened in accordance with the additional weight but by a lesser amount. In the above examples 30 gms and between 40 to 50 gms is preferably removed from the head respectively.

Tests on clubs designed with this principle show that 75 to 150 gms added in the gripping area is able to produce good conditions for all of the golfers tested. In addition, tests on a professional swing show that the clubhead is easier

to control. The golfer can rotate the head and bring it to square on impact much more easily than with the standard head.

Finally, the forces causing bending of the shaft are lower. The accelerations throughout the swing are large, particularly during the important second phase. These act through the centre of gravity of the system, which for most golf clubs is offset from the line of the shaft. This offset force produces significant bending in the shaft which will be reduced if the proposed design is adopted, and there is less weight in the head. With less bending the face of the club is less angled on impact. The shaft is therefore redesigned if necessary to compensate for this.

Most of this design method has referred exclusively to 'iron' golf clubs. It is equally applicable to the driver (Figure 2) or to the putter, although it is likely to have more effect on the swing of the former than the latter.

Design of golf club.

Typical designs are shown in Figures 3 and 4. In Figure 3 the additional weight W, of at least 50 gms, is placed in or around the gripping area of the club with its centre of gravity within 300 mm of the butt end of the shaft. This may be distributed as a solid (Figure 4a, 4e) or hollow section (Figures 4c, 4d) typically over 10 cms, or as a concentrated load (Figure 4b) such as a spherical ball B placed firmly into the tube up to 300 mm from the butt end supporting lead shot L held in place by a cork C or sleeved inside and/or outside the shaft (Figure 4f) or contained within the make up of a heavy grip (Figure 4g). The ball fixing has the advantage that contact is made with the tapered shaft over a small area thus creating the least change to the handling characteristics of the shaft. With any of the distributed weight systems the shaft may be slightly stiffened over the area of contact producing less deflection and a different flex point in the shaft. Calculations show that the stiffening effect is very small on most shafts but the same calculations can be used to redesign the shaft to have the original desirable characteristics.

In Figure 4d, the shaft is shown made of stepped steel in the conventional way with a thicker section. In shafts of reinforced plastic the weight, in any of the forms mentioned above, can be cast in during the manufacture of the shaft.

The clubhead must be lighter than standard. For the wooden headed club removal of the central section of the head around the centre of gravity and the lead weight normally placed there would produce a weight reduction of 15 to 25 gms. It is essential to remove more than this, but since this is impracticable for strength reasons, a redesign of the clubhead will be required. More ideal is the metal headed wood which is cast. This clubhead can either be made from lighter material of sufficient strength or by removing metal from least sensitive stress areas. The irons can be treated similarly, using lighter materials or conventional materials of different design, perhaps with hollow sections.

Claims

1. A golf club comprising a grip for gripping by the player, a shaft and a head the club including an additional weight, the club having a weight of between 350 and 630g, characterised in that the weight of the head is either between 160 and 260g or is 270g and the weight of the grip with the additional weight is between 85 and 210g, in which the additional weight is distributed over the gripping area, in which the centre of gravity of the additional weight is within 300 millimetres from the butt end of the shaft and in which the centre of gravity of the additional weight is not above the intended position of the golfers hands.

2. A golf club as claimed in claim 1 in which the additional weight is at least 50 g.

3. A golf club as claimed in claim 1 in which the additional weight is from 80 to 160 g.

4. A golf club as claimed in any one of claims 1 to 3 in which the shaft of the club is hollow and in which the additional weight is mounted inside the shaft.

5. A golf club as claimed in any one of claims 1 to 3 in which the additional weight is included in the grip.

6. A golf club as claimed in any one of claims 1 to 3 in which the shaft of the club is hollow and in which the additional weight is included in the shaft in the gripping area.

7. A set of golf clubs, each golf club in said set being characterised as in claim 1.

8. A method of matching a golf club to a player, said golf club including a head, a shaft and a grip at a butt end of the shaft comprising the steps of

   selecting a golf club having for the player an inertia ratio in the range as shown in the lower part of Figure 2 and having a known weight of head, a known weight of shaft and a known weight of grip.

selecting a reduction in the weight of the head of 30g or between 40g to 50g,

selecting a value for an additional weight to be distributed over the gripping area, said additional weight being between 50 to 160 g such that the inertia ratio $(I + MR^2/I)$ of the club for the player is greater than the minimum for that club as shown in the upper part of Figure 2, in which I is the moment of inertia of the club about the golfer's wrists, M is the total weight of the golf club and R is the effective length of the golfer's arms, and such that the inertia of the club in the first phase of a golfers swing is substantially the same as the golf club having the known weight of head, the known weight of shaft and the known weight of grip, in which the inertia of the club is the second phase of the golfers swing is substantially reduced from the inertia of the club having the known weight of head, the known weight of shaft and the known weight of grip, in which the centre of gravity of the additional weight is within 300 millimetres from the butt end of the shaft and in which the centre of gravity of the additional weight is not above the intended position of the golfers hands.

Patentansprüche

1. Golfschläger mit einem Griff zum Ergreifen durch den Spieler, einem Schaft und einem Schlägerkopf, wobei der Schläger ein zusätzliches Gewicht aufweist, der Schläger ein Gewicht zwischen 350 g und 630 g besitzt, **dadurch gekennzeichnet**, daß das Gewicht des Schlägerkopfes entweder zwischen 160 g und 260 g oder 270 g beträgt und das Gewicht des Griffes mit dem zusätzlichen Gewicht zwischen 85 g und 210 g liegt, wobei das zusätzliche Gewicht über den Griffbereich verteilt ist, das Schwerkraftzentrum des zusätzlichen Gewichts innerhalb einer Entfernung von 300 mm von dem dicken Ende des Schaftes entfernt angeordnet ist und das Schwerkraftzentrum des zusätzlichen Gewichts sich nicht oberhalb der angestrebten Position der Hände des Golfers befindet.

2. Golfschläger nach Anspruch 1, **dadurch gekennzeichnet**, daß das zusätzliche Gewicht mindestens 50 g beträgt.

3. Golfschläger nach Anspruch 1, **dadurch gekennzeichnet**, daß das zusätzliche Gewicht zwischen 80 g und 160 g beträgt.

4. Golfschläger nach einem der Ansprüche 1 bis 3, **dadurch gekennzeichnet**, daß der Schaft des Schlägers hohl ausgebildet ist und daß das zusätzliche Gewicht in dem Schaft angeordnet ist.

5. Golfschläger nach einem der Ansprüche 1 bis 3, **dadurch gekennzeichnet**, daß das zusätzliche Gewicht in den Griff integriert ist.

6. Golfschläger nach einem der Ansprüche 1 bis 3, **dadurch gekennzeichnet**, daß der Schaft des Schlägers hohl ausgebildet ist und daß das zusätzliche Gewicht im Griffbereich in dem Schaft angeordnet ist.

7. Ein Satz Golfschläger, **dadurch gekennzeichnet**, daß jeder Golfschläger die Merkmale des Anspruchs 1 aufweist.

8. Verfahren zum Anpassen eines Golfschlägers an einen Spieler, wobei der Golfschläger einen Schlägerkopf, einen Schaft und einen Griff an einem dicken Ende des Schaftes aufweist, gekennzeichnet durch die folgenden Schritte:

   Auswählen eines Golfschlägers mit einem Massen-Trägheits-Verhältnis im Bereich, wie dies in dem unteren Teil der Fig. 2 dargestellt ist, und mit einem bekannten Gewicht des Schlägerkopfes, einem bekannten Gewicht des Schaftes und einem bekannten Gewicht des Griffes, für den Spieler,

   Auswählen einer Reduzierung des Gewichts des Schlägerkopfes von 30 g oder zwischen 40 g und 50 g,

   Auswählen eines Wertes für ein zusätzliches Gewicht, welches über den Griffbereich verteilt wird, wobei dieses zusätzliche Gewicht zwischen 50 g und 160 g beträgt, so daß das Massen-Trägheits-Verhältnis $(I + MR^2/I)$ des Golfschlägers für den Spieler größer ist als das Minimum für diesen Schläger wie es in dem unteren Teil der Fig. 2 dargestellt ist, wobei I das Massen-Trägheitsmoment des Schlägers um die Handgelenke des Golfers, M das Gesamtgewicht des Schlägers und R die effektive Länge der Arme des Golfers ist, und die Massen-Trägheit des Schlägers in der ersten Phase des Schwungs im wesentlichen die gleiche ist wie bei einem Schläger mit bekanntem Gewicht des Kopfes, bekanntem Gewicht des Schaftes und bekanntem Gewicht des Griffs, und in einer zweiten Phase des Schwungs gegenüber der Massen-Trägheit eines Schlägers mit bekanntem Gewicht des Kopfes, bekanntem Gewicht des Schaftes und bekanntem Gewicht des Griffs wesentlich reduziert ist, wobei das Zentrum der Schwerkraft des zusätzlichen Gewichts innerhalb einer Entfernung von 300 mm von dem dicken Ende des Schaftes entfernt angeordnet ist und das Schwerkraftzentrum des zusätzlichen Gewichts sich nicht oberhalb der angestrebten Position der Hände des Golfers befindet.

Revendications

1. Club de golf comprenant une poignee destinee a être saisie par le joueur, un manche et une tête, le club comprenant un poids supplémentaire, le club ayant un poids compris entre 350 et 630 g, caracterisé en ce que le poids de la tête est compris entre 160 et 260 g ou est de 270 g, et le poids de la poignee avec le poids supplémentaire est compris entre 85 et 210 g, dans lequel le poids supplementaire est distribué sur la region de saisie, dans lequel le centre de gravité du poids supplementaire est à moins de 300 millimetres de l'extrémité du manche et dans lequel le centre de gravité du poids supplémentaire n est pas au-dessus de l'emplacement destiné aux mains du golfeur.

2. Club de golf selon la revendication 1, dans lequel le poids supplémentaire est de 50 g au moins.

3. Club de golf selon la revendication 1, dans lequel le poids supplémentaire est compris entre 80 et 160 g.

4. Club de golf selon l'une quelconque des revendications 1 à 3, dans lequel le manche du club est creux et dans lequel le poids supplémentaire est monte a l'interieur du manche.

5. Club de golf selon l'une quelconque des revendications 1 à 3, dans lequel le poids supplémentaire est inclus dans la poignée.

6. Club de golf selon l'une quelconque des revendications 1 à 3, dans lequel le manche du club est creux et dans lequel le poids supplémentaire est inclus dans le manche dans la région de saisie.

7. Jeu de clubs de golf, chaque club de golf dudit jeu etant caracterise selon la revendication 1.

8. Procédé d'adaptation d'un club de golf à un joueur, ledit club de golf comprenant une tête, un manche et une poignée a une extrémité du manche, comprenant les étapes suivantes :

sélectionner un club de golf ayant pour le joueur un rapport d'inertie dans la plage indiquée à la partie inférieure de la figure 2 et ayant une tête de poids connu, un manche de poids connu et une poignee de poids connu,
sélectionner une réduction du poids de la tête de 30 g ou entre 40 g et 50 g,
sélectionner une valeur d'un poids supplémentaire à repartir sur la région de saisie, ledit poids supplémentaire étant compris entre 50 et 160 g de manière que le rapport d'inertie $(I - MR^2/I)$ du club pour le joueur soit superieur au minimum pour ce club tel qu'il est indiqué dans la partie supérieure de la figure 2, sur laquelle I est le moment d'inertie du club par rapport aux poignets du golfeur, M est le poids total du club de golf et R est la longueur utile des bras du golfeur, et tel que l'inertie du club dans la première phase d'un swing du golfeur soit sensiblement la même que celle du club de golf ayant une tête de poids connu, un manche de poids connu et une poignée de poids connu, dans lequel l'inertie du club dans la seconde phase du swing du golfeur est sensiblement réduite par rapport à l'inertie du club ayant la tête de poids connu, le manche de poids connu et la poignée de poids connu, dans lequel le centre de gravité du poids supplémentaire est à moins de 300 millimetres de l'extrémité du manche et- dans lequel le centre de gravité du poids supplémentaire n'est pas au-dessus de l'emplacement destine aux mains du golfeur.

Standard 6 iron

Added weight (gms)	distance below hands (mm) 0	50	75	100
50	3.7	3.7	3.6	3.5
75	5.5	5.4	5.3	5.1
100	7.3	7.1	6.9	6.7
125	8.9	8.7	8.5	8.2
150	10.5	10.3	10	9.7

Lightweight 6 iron

Added weight (gms)	distance below hands (mm) 0	50	75	100
50	4.1	4.1	4	3.8
75	6.1	6	5.8	5.6
100	7.9	7.8	7.6	7.3
125	9.8	9.6	9.3	8.9
150	11.6	11.3	10.9	10.5

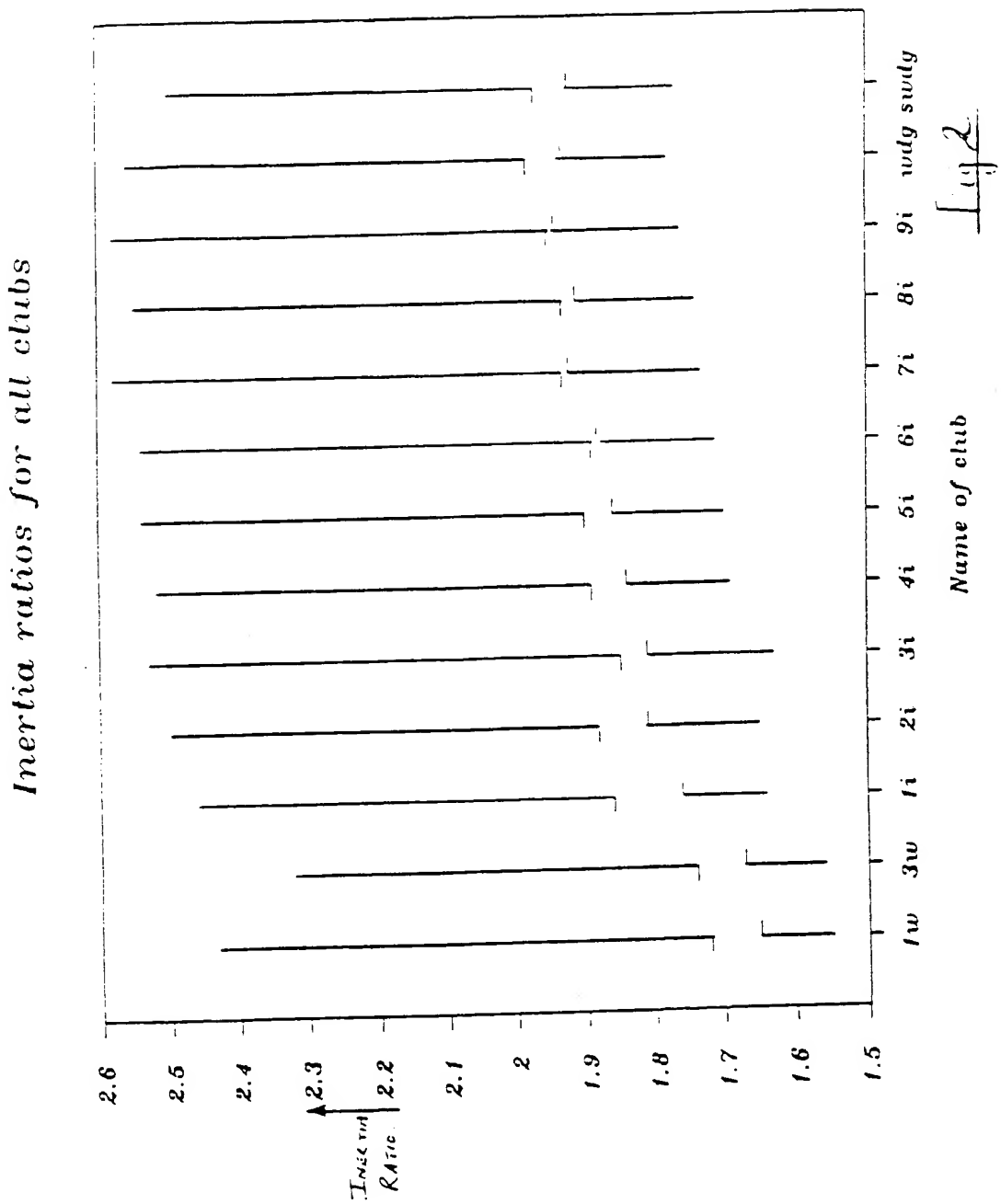
Standard driver

Added weight (gms)	distance below hands (mm) 0	50	75	100
50	4	3.9	3.8	3.7
75	5.8	5.7	5.6	5.4
100	7.7	7.5	7.3	7.1
125	9.4	9.2	9	8.7
150	11.1	10.8	10.6	10.3

Lightweight driver

Added weight (gms)	distance below hands (mm) 0	50	75	100
50	4.2	4.2	4.2	3.9
75	6.2	6.1	6	5.8
100	8.1	8	7.9	7.5
125	10	9.9	9.8	9.2
150	11.8	11.6	11.2	10.8

Figure 1 Percentage change to the torque ratios


Inertia ratios for all clubs
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
Inertia Ratio
1w
3w
1i
2i
3i
4i
5i
6i
7i
8i
9i
wdg
swdg
Name of club
Fig 2

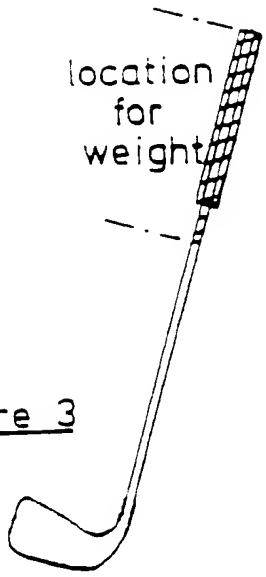


Figure 3

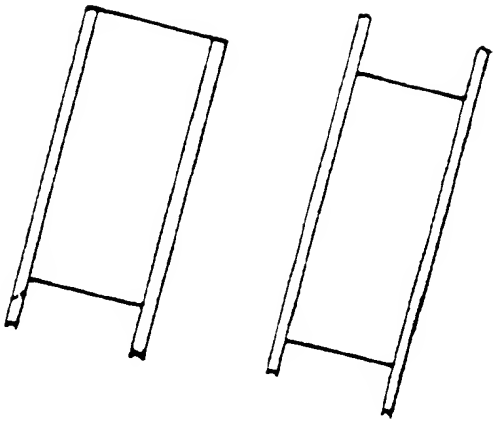
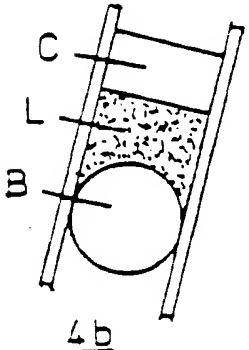
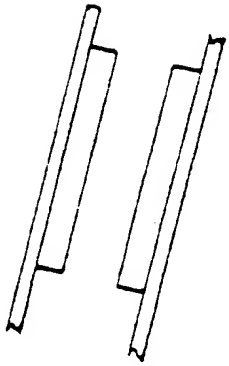


Figure 4a



4b



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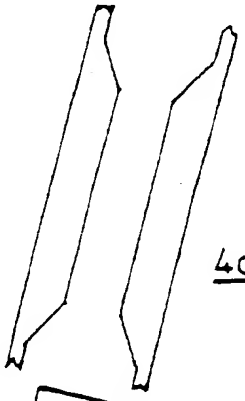

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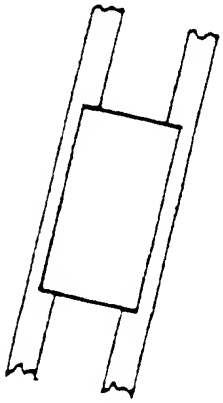

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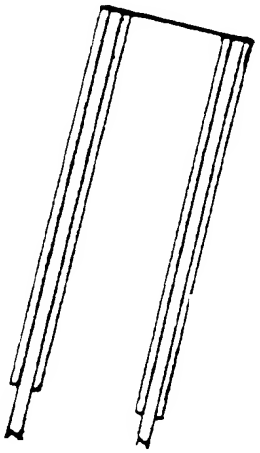
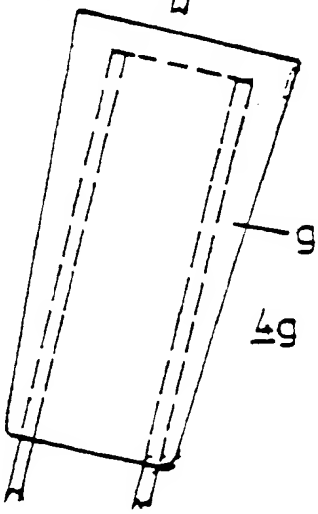


4f



4g